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Performance Analysis of Adhoc on Demand Distance Vector (AODV) and Destination Sequence Routing (DSR) Protocols in Mobile Adhoc Networks (MANET)

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Strictly as per the compliance and regulations of:

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I. Introduction

A mobile ad hoc network (MANET), also known as wireless ad hoc network or ad hoc wireless network is a continuously self-configuring, infrastructure-less network of mobile devices connected wirelessly. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. They may contain one or multiple and different transceivers between nodes. This results in a highly dynamic, autonomous topology.

The term ad hoc tends to "different forms" and can be "mobile, stand alone, or networked". A Mobile Ad hoc Network (MANET) is a self-organized wireless communication short lived network that contains collection of mobile nodes. The mobile nodes communicate with one another by wireless radio links without the use of any pre-established fixed communication network infrastructure or centralized administration, such as base stations or access points, and with no human intervention.

Self-organizing means that MANETs have the ability to spontaneously form a network of mobile nodes or hosts, merged together or partitioned into separate networks on-the-fly depending on the networking needs and dynamically handle the joining or leaving of nodes in the network. The major objectives of self organized MANET are: scalability, reliability, and availability. Mobile nodes are low capacity autonomous computing devices that are capable of roaming independently. Because of the fact that nodes are mobile, the network topology changes rapidly and unpredictably over time. Each mobile node acts as both a host and a specialized router to relay information (forward packets) to other mobile nodes. The success of the communication highly depends on the other nodes' cooperation. The nodes themselves are responsible for dynamically discovering other nodes to communicate in radio range.

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Figure 1.1: Mobile Ad hoc Network (MANET)

Typical MANET nodes are Laptops, PDAs, Pocket PCs, Cellular Phones, Internet Mobil Phones, Palmtops or any other mobile wireless devices. These devices are typically lightweight and battery operated. Figure 1.1 illustrates an example of a MANET and its communication technology which contains one PDA, one pocket PC, one laptop, one mobile phone and one mobile device. Since mobile phone is outside pocket PC's transmission range, the data from pocket PC to mobile phone must be retransmitted by laptop.

II. Characteristics of Manet

The main characteristics of MANETs are: the complete lack of centralized control, lack of association among nodes, rapid mobility of hosts, frequent dynamically varying network topology, shared broadcast radio channel, insecure operating environment, physical vulnerability and limited availability of resources, such as CPU processing capacity, memory power, battery power, and bandwidth.

- *Dynamic Network Topologies:* The nodes in MANETs are free to move independently in any direction. The network's wireless topology may change frequently and randomly at unpredictable times and primarily consists of bidirectional links.
- *Low Bandwidth:* These networks have lower capacity and shorter transmission range than fixed infrastructure networks. The throughput of wireless communication is lesser than wired communication because of the effect of the multiple access, fading, noise, and interference conditions.
- *Limited Battery Power:* The nodes or hosts operate on small batteries and other exhaustible means of energy. So, energy conservation is the most important design optimization criteria.
- *Decentralized Control:* Due to unreliable links, the working of MANET depends upon cooperation of participating nodes. Thus, implementation of any protocol that involves a centralized authority or administrator becomes difficult.
- *Unreliable Communications:* The shared-medium nature and unstable channel quality of wireless links may result in high packet-loss rate and re-routing instability, which is a common phenomenon that leads to throughput drops in multi-hop networks. This implies that the security solution in wireless ad hoc networks cannot rely on reliable communication.
- *Weak Physical Protection:* MANETs are more prone to physical security threats than fixed-cable nets. Mobile nodes are usually compact, soft and hand-held in nature. Today, portable devices are getting smaller and smaller. They could get damaged or lost or stolen easily and misused by an adversary. The increased possibility of different types of attacks should be carefully considered.
- *Scalability:* Due to the limited memory and processing power on mobile devices, the scalability is a key problem when we consider a large network size. Networks of 10,000 or even 100,000 nodes are envisioned, and scalability is one of the major design concerns.

III. Applications of Manets

There are many applications of MANETs. The domain of applications for MANETs is diverse, ranging from small, static networks that are constrained by power sources to large-scale, mobile, highly dynamic networks. Significant examples include establishing survivable, efficient, dynamic communication for: network-centric military/battlefield environments, emergency/rescue operations, disaster relief operations, intelligent transportation systems, conferences, fault-tolerant mobile sensor grids, smart homes, patient monitoring, environment control, and other security sensitive applications. Most of these applications demand a specific security guarantees and reliable communication. Some well known applications are:

- *Military Tactical Operations:* For fast and possibly short term establishment of military communications and troop deployments in hostile and/or unknown environments.
- *Search and Rescue Operations:* For communication in areas with little or no wireless infrastructure support.
- *Disaster Relief Operations:* For communication in environments where the existing infrastructure is destroyed or left inoperable.
- *Law Enforcement:* For secure and fast communication during law enforcement operations.
- *Commercial Use:* For enabling communications in exhibitions, conferences and large gatherings. For some business scenarios, the need for collaborative computing might be more important outside office environments than inside a building. After all, it is often the case where people do need to have outside meetings to cooperate and exchange information on a given project.

IV. Dynamic Source Routing (DSR) Protocol

It is a reactive protocol that creates a route on demand using source routing protocol i.e. it requires a full series of paths to be established between source and destination nodes to transmit packets and each packet follows the same path. The major motivations of this protocol are to limit the bandwidth by avoiding the periodic table updates and long convergence time. The underline fact to this protocol is that it floods a route request message in the network to establish a route and it consists of two procedures: Route Discovery and Route Maintenance.

a) *Route Discovery*

As it is an on-demand routing protocol, so it looks up the routing during transmission of a packet. At the first phase, the transmitting node search its route cache to see whether there is a valid destination exists and if so, then the node starts transmitting to the destination node and the route discovery process end here. If there is no destination address then the node broadcasts the route request packet to reach the destination. When the destination node gets this packet, it returns the learned path to the source node.

b) *Route Maintenance*

It is a process of broadcasting a message by a node to all other nodes informing the network or node failure in a network. It provides an early detection of node or link failure since wireless networks utilize hop-to-hop acknowledge.

The advantage of this protocol is:

1. Aware of existence of alternative paths that helps to find another path in case of node or link failure.
2. It avoids routing loops.
3. Less maintenance overhead cost as it an on-demand routing protocol.

The disadvantage of this protocol is:

1. Long route acquisition delay for the route discovery which may not be acceptable in situations like the battle field.
2. It is not suitable for large number of nodes where speed may suffer.
3. It produced huge messaging overhead during busy times.

V. Ad-Hoc on-Demand Distance Vector (AODV) Protocol

It is a classical routing protocol for MANETs that compromise the trade-off problems like large packet header in reactive source protocol and large messaging overhead due to periodic updates in proactive protocols. It uses a distributed approach i.e. it keeps track of the neighbor nodes only and it does not establish a series of paths to reach the destination. It also uses route discovery and route maintenance mechanism like DSR.

a) *Route Discovery*

A source node send a broadcast message to its neighboring nodes if no route is available for the desired destination containing source address, source sequence number, destination address, destination sequence number, broadcast ID and hop count. Two pointers such as forward pointer and backward pointer are used during route discovery. Forward pointers keep track of the intermediate nodes while message being forwarded to destination node. Eventually, when route request message reached the destination node, it then unicast the reply message to the source via the intermediate nodes and the backward pointer keeps track of the nodes. The major feature of AODV that distinguish it from DSR is the destination sequence number which is used to verify the up-to-date path to the destination.

b) *Route Maintenance*

Three types of messages exchanged between source and destination such as route error message, hello message and time out message. Route error message ensures that this message will be broadcasted to all nodes because when a node observes a failed link, it will propagate this message to its upstream nodes towards source node only. Hello message ensures the forward and backward pointers from expiration. Time out message guarantees the deletion of link when there is no activity for a certain amount of time between source and the destination node.

The advantage of this protocol is:

1. It is an efficient algorithm for mobile ad-hoc networks and it is scalable.
2. It takes short time for convergence and is a loop free protocol.
3. Messaging overhead to announce the link failure is less compared DSR.

The disadvantage of this protocol is:

1. It needs huge bandwidth to keep maintain periodic hello message.

VI. Simulation Experiments

Experimental modeling, design, results and analysis are described below to compare the performance of two routing protocols such as DSR and AODV.

a) *Experimental Design*

Simulation experiments were run on two desktop PCs with different speed and memory capacity though there were no effects of speed and memory capacity on the experimental results.

Mean end-to-end delay, packet delivery rate and routing overhead as measured by the number of control packets generated for routing are the performance matrices that were used to compare the two routing protocols.

i. *Mean end-to-end delay:* Average time taken for a packet to travel from source to destination including route acquision delay.
ii. *Packet delivery rate:* Ratio of packets successfully delivered to the destination to the total number of packets transmitted by the source node.
iii. *Messaging overhead:* Total number of control packets generated for routing.

Node density, node mobility and traffic are the three control parameters used for this simulation. Mean end-to-end delay, packet delivery rate and routing overhead were measured for node mobility in experiment 1 and node density were for three different levels of traffic load in experiment 2. Constant bit rate generator was used for generating packets of fixed size. Three different types of traffic load were used for simulation such as.

1. *Low traffic load:* One packet transmitted every 10 seconds
2. *Medium traffic load:* One packet every second.
3. *High traffic load:* One packet every 0.1 second.

The following are the parameters that were used for configuring input file in the simulation:

1) Terrain size: 200 m X 200 m
2) Radio signal transmission range: 175 m
3) Link bandwidth: 2 Mbps
4) Simulation time: 500 s
5) Packet size: 1460 bytes
6) Node placement: Random Way Point
7) Propagation model: Free space
8) Transport layer protocol: UDP
9) MAC layer protocol: IEEE 802.11
10) Routing protocol: AODV and DSR
11) Number of nodes: 50, 75 and 100 respectively
12) Number of packet sender nodes: 25 (randomly selected)
13) Number of packet receiver nodes:25 (randomly selected)
14) Node speed: 45 km/h
15) Pause time: 0s, 120s, 300s, 400s and 500s respectively.
16) Seed value: Randomly selected between 1 and 10

VII. Experimental Results and Analysis

Table 1 represents the number of control packets observed for the five different levels of node mobility and three different levels of node density at different traffic loads. The left half of Table 1 under column heading 'Node Mobility' shows that DSR produced highest number of packets such as 220 in node mobility under low traffic load. It also shows that AODV produced highest number of packets such as 1521 and 5952 under medium and high traffic loads respectively due to high messaging overhead. The ratio of control packets generated at perpetual node mobility under low, medium and high traffic loads in AODV was calculated as 111.54%, 395.04% and 468.29% respectively. It was 110%, 220.58% and 161.95% at perpetual node mobility under low, medium and high traffic loads respectively. It shows that DSR is less vulnerable to node mobility in terms routing overhead.

Table 1: Number of control packets observed for the five different levels of node mobility and three different levels of node density.

		Node Mobility					Node Density		
Load	Protocol	Perpetual	High	Medium	Low	Zero	High	Medium	Low
Low	AODV	174	171	162	156	156	399	307	192
	DSR	220	220	215	200	200	249	210	200
Medium	AODV	1521	857	652	522	385	1159	993	853
	DSR	986	808	510	498	447	885	679	338
High	AODV	5952	4759	4747	2963	1271	5139	3473	1318
	DSR	1009	885	679	638	623	1109	988	468

Figure 1 represents the number of control packets generated at different node mobility under high traffic load. The rate of increasing control packets from traffic load low to high under perpetual node mobility was 34.20 times (174 in Low and 5952 in High) but it was 4.59 times (220 in Low and 1009 in High) in DSR. These results show that is not suitable for network scalability in terms of messaging overhead.

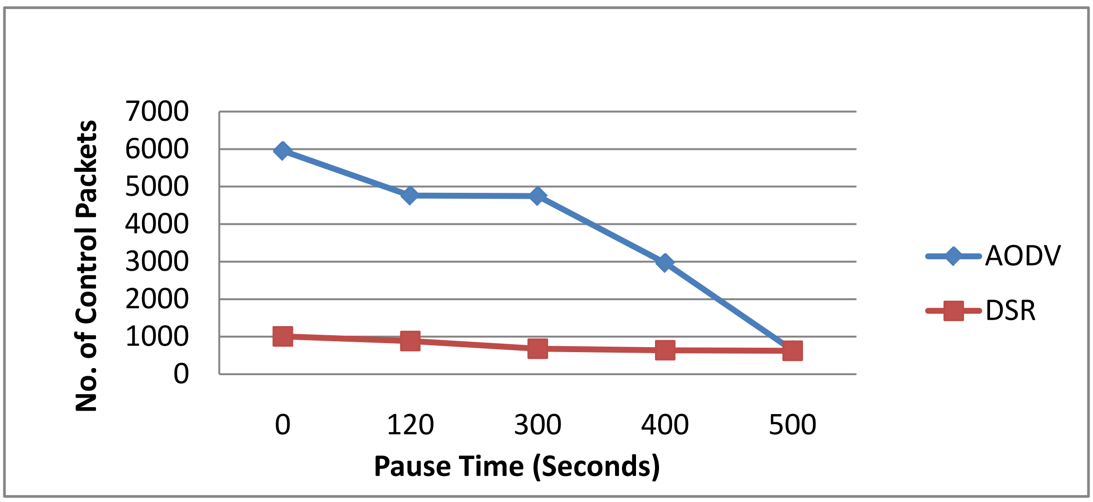

Figure 1: Control overhead for various node mobility levels at high traffic load.

Table 2 shows the percentage rate of packet delivery at node mobility and node density under low, medium and high traffic loads. From left half of Table 2, it was observed that the lowest and highest rate of packet delivery for DSR was 1.96% and 10.34% and for AODV was 3.51% and 9.13% as AODV does not maintain complete sequence of paths between intermediate nodes, so there may have possibilities to lost packets.

Table 2: Packet delivery rate (%) for the five different levels of node mobility and three levels of node density.

		Node Mobility					Node Density		
Load	Protocol	Perpetual	High	Medium	Low	Zero	High	Medium	Low
Low	AODV	5.18	3.51	4.12	4.49	4.32	4.63	6.88	3.87
	DSR	2.59	2.59	2.09	1.96	1.96	6.1	1.38	1.96
Medium	AODV	4.48	5.10	10.23	7.47	4.73	5.65	5.45	5.18
	DSR	6.71	5.89	5.84	5.86	5.95	5.46	7.03	7.96
High	AODV	7.42	7.62	8.83	8.88	9.13	8.30	8.33	8.14
	DSR	8.84	9.09	9.23	9.92	10.34	6.91	6.70	6.23

Figure 2 shows the packet delivery rate for five different levels of node mobility at high traffic load. Packet delivery rate depends on several factors such as 1) number of packets to be sent, packet size, start and end time during simulation and interdeparture time of the Constant Bit Rate generator and these are determined by the experimenter. If the experimenter chooses small number of packets to be sent of smaller size with larger difference between start and end time during simulation and a big interdeparture time, the source delivers all or most of the packets to the destination irrespective of the routing protocols. These factors also greatly affect the number of control packets to be generated.

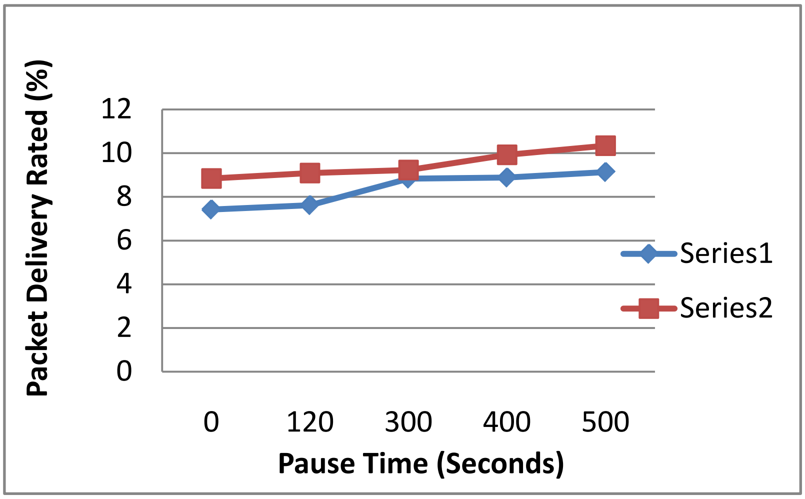

Figure 2: Packet delivery rate for five different levels of node mobility at high traffic load.

Figure 3 shows the percent ratio of packet delivery rate at perpetual mobility to zero mobility. It showed that the packet delevery rate was least affecteed in AODV compared to DSR to increase traffic load.

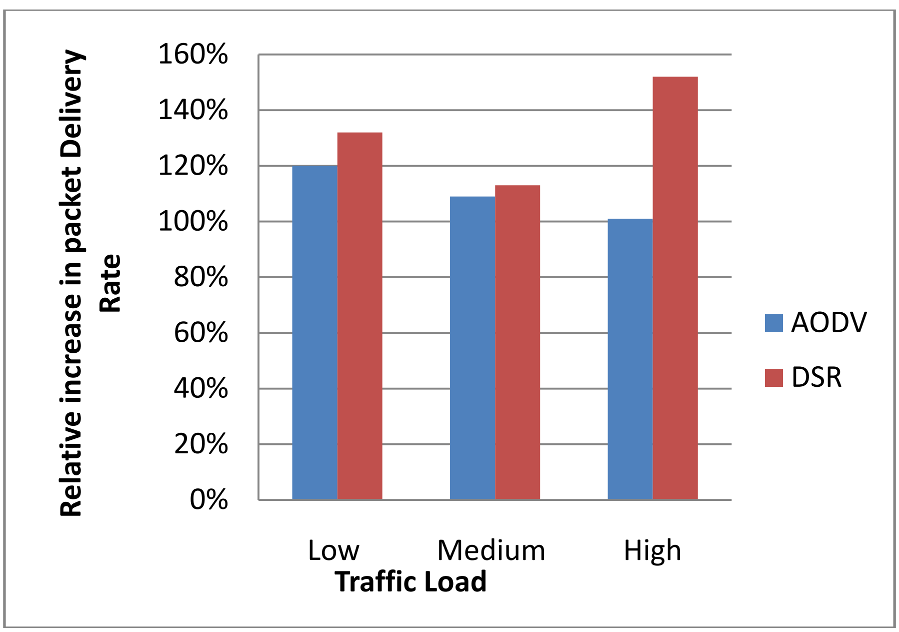

Figure 3: The relative decrease in packet delivery rate when mobility was decreased to zero mobility.

The left half of the Table 3 shows mean end-to-end delay in seconds for five levels of node mobility for AODV and DSR. DSR resulted longest end-to-end delay except for high node mobility. AODV took more than 5 times end-to-end delay compared to DSR at Perpetual in high level of node mobility.

Table 3: Mean end-to-end delay (in seconds) for the five different levels of node mobility and the three different levels of node density.

		Node Mobility					Node Density		
Load	Protocol	Perpetual	High	Medium	Low	Zero	High	Medium	Low
Low	AODV	0.39	0.21	0.33	0.18	0.11	0.44	0.24	0.12
	DSR	0.57	0.51	0.32	0. 29	0.28	0.62	0.48	0.39
Medium	AODV	0.18	0.06	0.08	0.04	0.03	0.10	0.70	0.60
	DSR	0.73	0.35	0.37	0.33	0.41	0.45	0.42	0.40
High	AODV	3.67	4.07	4.58	3.98	2.87	3.97	2.28	1.74
	DSR	0.68	0.79	0.33	0.30	0.07	0.75	0.49	0.21

Figure 4 represents the number of messaging overhead observed at three different levels of node density at high traffic load. The right half of Table 1 under column heading 'Node density' shows that AODV produced highest number of packets such as 399, 1159 and 5139 under low, medium and high traffic loads respectively due to high messaging overhead. It was 249, 855 and 1109 for DSR. There was a rapid increase in control packets in AODV from 399 at low traffic load to 5139 at high traffic load which and the increasing rate was 12.88. From Figure 4, it can bee seen that the number of control packets for AODV sharply increased from 1318 at low density to 5139 at high density under high traffic load and increasing rate is 389.90%. There is a little variation of control packets generated for DSR which is 641(1109 – 468).

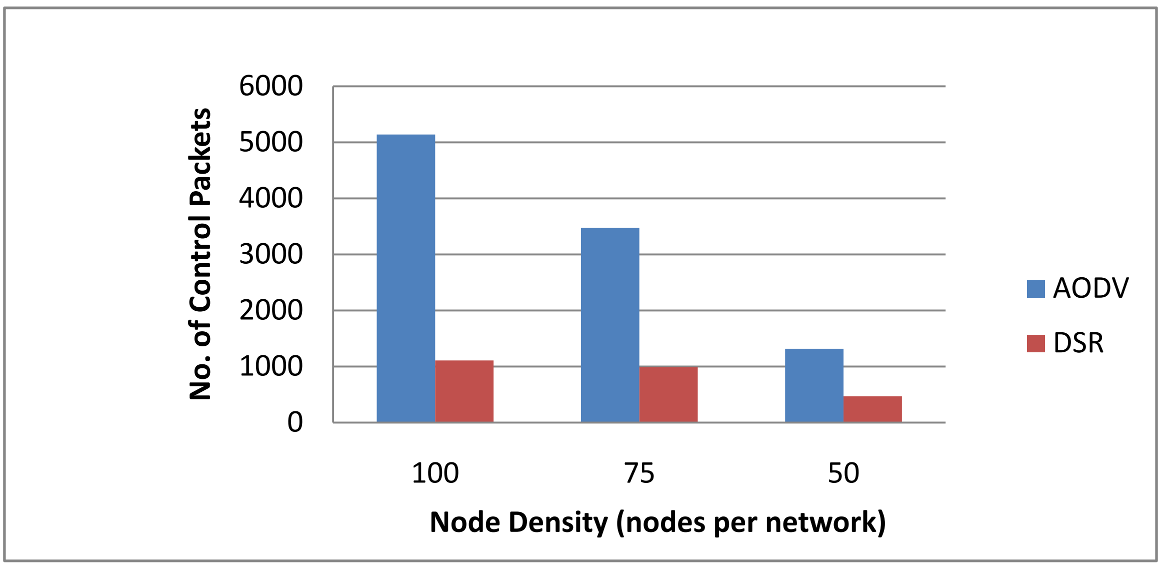

Figure 4: Messaging overhead for three different levels of node density at high traffic load.

Figure 5 shows the ratio of the number of control packets observed at high node density to low node density. The ratio of control packets generated at high node density to low node density under low, medium and high traffic loads in AODV was calculated as 207.81%, 135.83% and 389.90% respectively. It was 124.50%, 261.83% and 236.96% for DSR. It shows that DSR is less vulnerable to node density in terms routing overhead.

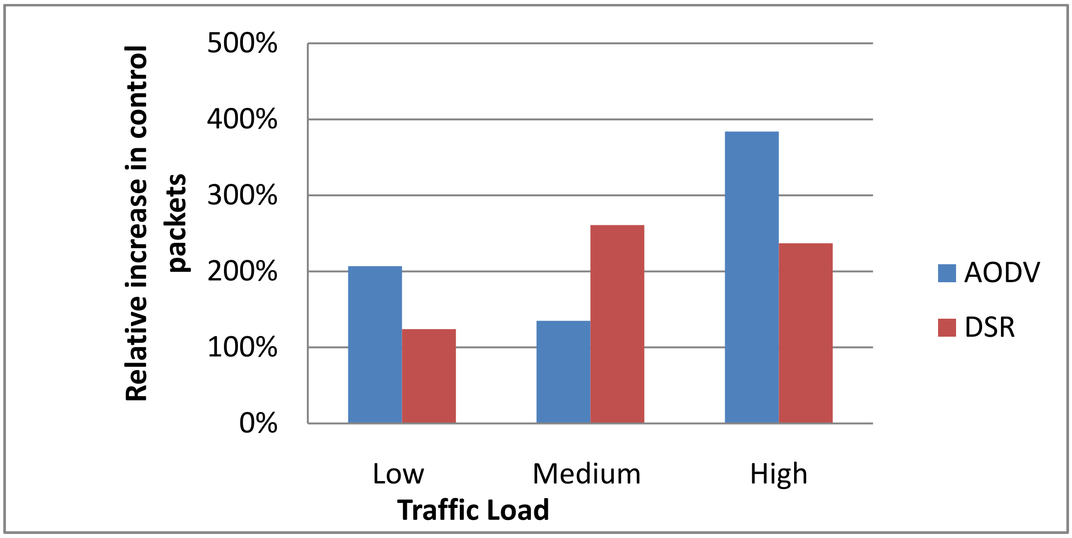

Figure 5: The ratio of the number of control packets observed at high node density to that observed at low node density.

VIII. Conclusions

A comparison between AODV and DSR routing protocol MANETs has been made in this report based on number of control packets, mean end-to-end delay and messaging overhead. AODV produced higher control packets compared to DSR. The rate of increasing control packets from traffic load low to high under perpetual node mobility was 34.20 times (174 in Low and 5952 in High) but it was 4.59 times (220 in Low and 1009 in High traffic load) in DSR. The rate of increasing control packets from traffic load low to high under high node density was 12.88 times (399 in Low and 5139 in High traffic load) but it was 4.45 times (249 in Low and 1109 in High) in DSR. It shows that DSR is less vulnerable to node mobility and node density in terms routing overhead. DSR produced least messaging overhead compared to AODV in both the experiments because DSR does not send periodic hello messages during simulation. This means that DSR is best suited for scalability.

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